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THE AMERICAN

METEOROLOGICAL JOURNAL.

VOL. XI. BOSTON, MASS., DECEMBER, 1894. No. 8.

CYCLONIC PRECIPITATION IN NEW ENGLAND.*

(*Continued.*)

PROF. WINSLOW UPTON.

TABLE XVI.

CYCLONES WHICH MOVED FROM THE SOUTH NEAR NEW ENGLAND.

No.	Date of Passage.	Pressure at Centre. (Inches.)	Hourly Velocity. (Miles.)	Precipitation.			
				Kind.	Maximum Area.		
					Amount. (Inches.)	Distance from Path. (Miles.)	Direction from Path.
220	March 10, 1887	29.6d	25	Rain and Snow.	2.2	—	—
221	April 18, "	29.4	45	Rain and Snow.	0.9	—	—
222	Aug. 25, "	—	25	Rain.	2.2	400	NW.
223	Dec. 15, "	29.3d	30	Rain and Snow.	0.8	190	NW.
224	April 20, 1888	29.6d	20	Rain and Snow.	0.8	300	NW.
225	Dec. 11, "	29.3d	30	Rain and Snow.	2.2	—	—
226	Jan. 7, 1889	29.4	15	Rain.	3.5	—	—
227	March 17, "	29.7	25	Rain.	2.5	—	—
228	Oct. 24, 1890	29.6i	15	Rain.	4.5	100	NW.
229	Dec. 18, "	29.3d	50	Rain and Snow.	3.0	125	NW.
230	Jan. 5, 1891	29.8d	25	Snow.	0.9	—	—
231	Jan. 18, "	29.9	15	Rain and Snow.	3.0	140	NW.
232	Jan. 25, "	29.5	30	Snow.	1.6	200	NW.
233	Oct. 13, "	29.7	35	Rain.	4.0	110	NW.
234	Nov. 29, "	29.7d	20	Rain and Snow.	2.0	—	—

NOTES.

The following facts regarding the cyclones of the preceding table are to be added to the tabulated data.

* Read before the New England Meteorological Society, at Boston, Mass., April 21, 1894.

In all cases the storm centre passed east of southern New England, moving northeasterly: —

Nos. 220, 224, 234, formed near the middle Atlantic coast.

Nos. 221, 223, 225, 226, 228, 229, 231, 232, reached the middle Atlantic coast, having come from the Gulf of Mexico, or its vicinity.

Nos. 222, 227, 230, 233, came up the Atlantic coast east of the shore line.

No. 222 was a tropical hurricane, and very severe in the Atlantic.

Nos. 220, 221, 225, 226, 227, 230, 234, gave their heaviest precipitation on the southeast coast, with a less amount inland. The lack of data from the ocean prevents our assuming that the amount did not increase towards the track itself, and necessitates blanks in the seventh and eighth columns of the tables.

From the data collected in these tables, the following facts are derived, the numbering continued from the earlier part of this report: —

9. The velocity with which the storms passed New England ranged between 10 and 50 miles per hour.

10. Of the 25 storms whose tracks crossed New England, 5, or 20 per cent, were diminishing in energy, 13, or 52 per cent, increasing in energy, and 7, or 28 per cent, showed no change in energy while within the region of observation. The proportion is about the same as already noted for storms of Class I.

11. Similarly, for the 15 storms whose paths were east of New England, 1 was diminishing in energy, 7 increasing in energy, and, for 7, this was undetermined, because the storm was too far away from the land to give the required data.

If we combine with these figures those given in the preliminary study of the earlier cyclones, we find that of storms approching New England from the south, of which 53 in all have been studied, 28, or 53 per cent, showed increase in energy while passing this district, 9, or 17 per cent, were certainly diminishing in violence, and 16, or 30 per cent, were either unchanging in this respect, or the data were insufficient to determine the fact. We may say that, in general, one half of the storms which visit New England are increasing in violence, whether they come from the west or south, and that one half the remainder are diminishing in violence, and the others pass by without showing any material change in this respect.

12. The data of the sixth column show that the precipitation was large, reaching over 6 inches in the extreme case. The average for Table XV. is 2.4 inches, and for Table XVI. 2.3 inches. The corresponding average for

storms of Class I. was 1.6 inches. The amount of precipitation, therefore, of southern storms compares with that of western storms in the proportion 3 to 2.

13. The data of the seventh and eighth columns give the facts regarding the position of the region of greatest precipitation with regard to the path of the storm centre, and show that in these storms also the heaviest precipitation is not along the path in a majority of cases. Thus, of the 25 storms whose centres passed over New England, 5 had their greatest precipitation along the path, 2 had a maximum area east of the path, and 18 west of it. The paths were usually near the eastern part of the district, and, therefore, more favorable for showing a maximum area west of the central track than east of it.

14. For the storms whose tracks lay east of New England, the maximum precipitation, in eight cases, was west of the path, and in the other seven instances the data were insufficient to show whether the increase in the amount which was noted as the coast was approached from inland, continued in the ocean to the storm track or not.

15. The average distance of the area of greatest precipitation from the track of the centre of pressure is 73 miles for the 18 storms whose centres crossed New England, and gave a maximum precipitation on the left of the track, and 40 miles for the two cases in which the maximum area was on the right of the track.

16. Similarly, for the storms of Table XVI., the eight cases in which there was a well-marked maximum area at the left of the storm track, gave an average distance of 196 miles.

The preliminary paper gave 6 storms in which the centre crossed New England, with maximum precipitation west of the path, and 2 with the maximum east of it. The general average distance of a western maximum area is 72 miles, and of an eastern, 38 miles.

The result of this study, so far as it relates to the distribution of precipitation, is to confirm most emphatically the preliminary study. It is a very rare occurrence for the heaviest rainfall to occur along the path of the centre of pressure, and there is good evidence that there are a number of maximum areas on either side of the central path. The situation of New England is not favorable for the detection of maximum areas on both sides of the path of a given cyclone, because of its limited area. The large majority of cyclones which reach New England overland have their paths in the northern part of the district, or in the valley north of the boundary. The circumstances are favorable for the detection of maximum areas of precipitation on the right of the central track. These are brought out prominently in the above discussion, and in Tables XIII. and XIV. Similarly, the large majority of cyclones which come up the Atlantic coast

cross the southeastern part of New England, or pass east of the district in the ocean. The circumstances are favorable for the detection of maximum areas on the left of the storm track, and these are brought out prominently in the above discussion, and in Tables XV. and XVI. Wherever the path of a cyclone is so situated that the stations of observation are numerous on the other side of the central track, it is found that the precipitation is unequal on that side also, and that maximum areas occur on the left of the storms which come to New England overland from the west, and also on the right of the storms which come to New England from the south up the Atlantic coast. The preliminary study had established this fact plausibly for western storms, but with some doubt for southern storms. The present study makes it as certain for the latter as for the former class.

The explanation of anomalous distribution of rainfall and snowfall in cyclones must be sought in part in topography, and in part in the mechanism of the cyclone itself. That the latter is the stronger of the two elements is indicated by the extreme irregularity with which the maximum areas are located in the various parts of New England. There seems to be no tendency to preponderate on the windward sides of the mountains, or along the coast, for instance. Undoubtedly, were a close network of stations placed in any region of great topographic variety, as in New Hampshire for instance, local deviations in the distribution of precipitation would be found depending upon topography; but the deviations under discussion are on a broader scale, covering many square miles in which the smaller topographic variations are masked. Similar deviations may be found in the case of almost any well-developed cyclone in any part of the country. As it moves along it will deposit its greatest amount of rain or snow very irregularly, now along the path, now one hundred miles on the right or on the left, and so on. Another cyclone, moving in almost precisely the same path, will show equal irregularity in its precipitation, but not at all agreeing with the former in geographical distribution, as it would were topography the chief controlling cause. The cyclone contains in itself the forces which produce, to a great degree, the observed irregularity in its precipitation as it advances along its path.

RELATION OF THE RAIN AREA OF A STORM TO ITS BAROMETRIC CENTRE.

We come now to a discussion of the data regarding the movement of the rain area with regard to that of the barometric centre of the storm. This is given by the recorded times of the beginning and ending of rain and snow at the several observing stations. We are met at the outset by the inherent uncertainty attaching to the records. The time of beginning or ending of rain, and still more of snow, is difficult to determine, except in case of thunderstorms. Oftentimes cyclonic rains begin and end so gradually that discrepancies of hours may be found in adjacent records from the same town. One or the other of these events also may occur in the night and not be noted unless the observer has a self-recording gauge, of which few were in use in the period covered by these records. It is not surprising, therefore, that the data are meagre, and often conflicting. All of the reports, however, were tabulated through 1888, when it was thought inadvisable to extend this part of the investigation further. The following tables contain the result from such records as seemed sufficiently consistent to merit reliance. The first column is the current number of the storm in this paper; the second column contains the time in hours between the beginning of rain or snow and the passage of the storm centre by eastern Massachusetts; the third column gives the time after the passage of the centre until the rain or snow ceased. In the few cases in which the precipitation did not begin until after the passage of the centre, or ended before its passage, the minus sign is used. The fourth column is the sum of the second and third, and is, therefore, the duration of the precipitation. The fifth, sixth, and seventh columns give the hourly velocity of the rain front, barometric centre, and rain rear, respectively, while crossing New England.

TABLE XVII.

CLASS I.—STORMS FROM THE WEST WHOSE CENTRES PASSED OVER NEW ENGLAND.

No.	Interval between Rain front and centre.	Interval between centre and Rain rear.	Duration of Precipitation.	Hourly Velocity of Rain front.	Hourly Velocity of centre.	Hourly Velocity of Rain rear.
42	5	6	11	23	50	-
43	13	5	18	-	-	-
44	3	0	3	-	-	-
45	13	2	15	-	55	20
46	-	-	-	16	45	-
47	0	13	13	-	-	-
48	-	-	-	-	50	25
49	8	—2	6	37	40	22
50	16	—6	10	40	45	-
51	-	-	-	-	45	30
56	5	4	9	30	35	33
57	-	-	-	37	25	34
58	5	2	7	17	60	-
59	-	-	-	-	40	40
60	14	5	19	40	45	-
61	9	5	14	-	-	-
62	16	1	17	20	55	-
63	29	4	33	12	30	-
64	14	2	16	-	-	-
65	14	2	16	30	40	-
66	25	—9	16	17	30	-
71	31	—1	30	60	15	16
74	26	1	27	12	35	16
75	9	3	12	27	40	-
Average	13	2	15	28	41	26

TABLE XVIII.

CLASS I.—STORMS FROM THE WEST WHOSE CENTRES PASSED NEAR NEW ENGLAND.

No.	Interval between Rain front and centre.	Interval between centre and Rain rear.	Duration of Precipitation.	Hourly Velocity of Rain front.	Hourly Velocity of centre.	Hourly Velocity of Rain rear.
111	5	4	9	15	35	-
112	4	8	12	-	-	-
113	9	—1	8	30	15	-
114	20	0	20	-	45	10
116	3	4	7	-	-	-
117	11	12	23	-	50	18
118	15	7	22	-	-	-
121	26	—8	18	25	50	18
125	-	-	-	-	20	15
126	7	6	13	10	45	-
127	2	25	27	-	-	-
128	17	8	25	-	-	-
129	14	—1	13	6	25	-
130	25	—11	14	22	50	-
131	31	15	46	35	30	-
133	-	-	-	-	30	17
135	14	6	20	10	20	-
137	0	5	5	18	15	-
142	28	4	32	-	-	-
144	9	4	13	-	-	-
Average	13	5	18	19	33	16

TABLE XIX.

CLASS II.—STORMS FROM THE SOUTH WHOSE CENTRES PASSED OVER NEW ENGLAND.

No.	Interval between Rain front and centre.	Interval between centre and Rain rear.	Duration of Precipitation.	Hourly Velocity of Rain front.	Hourly Velocity of centre.	Hourly Velocity of Rain rear.
195	17	12	29	10	25	-
196	13	1	14	30	50	-
197	3	10	13	-	40	27
199	5	20	25	-	-	-
200	11	2	13	27	40	-
201	10	20	30	-	-	-
202	8	10	18	-	-	-
204	9	1	10	26	40	-
205	9	3	12	-	25	26
206	10	7	17	8	30	12
207	-	-	-	27	40	-
Average	10	8	18	21	36	22

TABLE XX.

CLASS II.—STORMS FROM THE SOUTH WHOSE CENTRES PASSED NEAR NEW ENGLAND.

No.	Interval between Rain front and centre.	Interval between centre and Rain rear.	Duration of Precipitation.	Hourly Velocity of Rain front.	Hourly Velocity of centre.	Hourly Velocity of Rain rear.
220	15	12	27	-	-	-
221	16	3	19	22	45	-
223	13	2	15	-	-	-
224	12	14	26	-	-	-
Average	14	8	22	-	-	-

These tables contain data from which the following results are derived, the numbering continued from the conclusions of the earlier part of this paper:—

17. The second, third, and fourth columns show that in eastern Massachusetts the interval of time between the beginning of rain or snow, and the passage of the centre of the depression is with few exceptions much longer than the corresponding time after the passage of the centre before the rain or snow ceases. This is simply another way of stating the well-known fact that the greater part of the precipitation area precedes the storm centre. In quite a number of instances, the minus sign in the fourth column shows that it stopped raining before the storm centre passed its nearest point to eastern Massachusetts. The centre, in only a few cases, passed directly over Massachusetts; in the storms of Tables XVII. and XIX., it was within the limits of New England, but in those of Tables XVIII. and XX., it was beyond these limits. The average duration of rain is about eighteen hours, of which about thirteen precede and five follow the barometric centre.

18. The fifth, sixth, and seventh columns show the relation which exists between the rates of the rain front, rain rear, and barometric centre. The preliminary study indicated that these rates were quite different, and this is abundantly confirmed by this larger investigation. It will be noticed that with very few exceptions the centre of pressure has a much greater velocity than that of the front or the rear of the precipitation. Thus in Table XVII., there are but two cases in which the rain front moved as fast as the storm centre, and three in which the rate of the rain rear equalled or exceeded that of the centre. The average hourly velocity of the rain front was twenty-eight miles, of the rain rear twenty-six miles, while that of the storm centre was forty-one miles. Similarly in Table XIX., while the data are more meagre, the same difference is noted, and there is but one case in which the storm centre moved as slowly as the rain front or rear. The

storms of Table XVIII. do not cross New England, so that the rates of the rain front or rear are for parts of the rain area far distant from the storm centre. But in their case also the rule holds with but three exceptions.

Examining these columns more closely it will be seen that there are only seven instances in which the velocity of both rain front and rain rear are determined. In two of these storms, Nos. 57 and 71, both rain front and rear moved slower than the storm centre; in the other five cases, both moved faster. In all other instances we have data for only the rain front or the rain rear, but not for both.

We might also notice whether there is any difference between storms increasing and those decreasing in energy. This has been done with the following results: —

(*a*) In storms whose centres crossed New England from the west, increasing in energy, the rain front moved slower than the centre in eight of the nine instances, and the rain rear in six of the eight instances. The average rate of the rain front is twenty-nine miles per hour, of the rain rear 22 miles per hour, and of the storm centre, 40 miles.

(*b*) In storms whose centres passed near, but not over, New England, coming from the west and increasing in energy, the rain front moved slower in two of the three instances, the average velocities being 20 and 37 miles, respectively.

(*c*) In storms crossing New England from the west with diminishing energy, the rain front moved slower in four of the five cases, the average velocities being 27 and 34 miles, respectively. There was but one case in which the velocity of the rain rear was determined, and it was greater than that of the centre.

(*d*) In storms passing beyond the New England boundary from the west with diminishing energy, the rain front moved slower in five of the seven cases, the average velocities being 17 and 27 miles, respectively, and the rain rear moved slower in all six cases, with the average velocities of 17 and 37 miles, respectively.

(*e*) In storms from the south, the energy was increasing in all cases where this could be determined. The rain front in all cases of Tables XIX. and XX., moved slower than the storm centre, the average velocities being 21 and 39 miles, respectively. The three cases in which the motion of the rain rear was noted give two of slower rate and one of faster rate than the barometric centre, with average velocities of 22 and 32 miles, respectively.

From these it will be seen that when a cyclone is passing over or near New England, the barometric centre does not occupy a constant position in the precipitation area. As the rates of both rain front and rain rear are roughly the same, it follows that the precipitation area is not contracting or expanding, but that the barometric centre itself is displaced in that area. In the great majority of cases it is moved forward in the

precipitation area, so that when the storm leaves New England the centre is nearer the rain front than when it entered the district. The numerical averages given above show that the difference in velocity is far greater than the unavoidable uncertainties of the data used in the discussion.

The cause of this displacement of the barometric centre in the precipitation area is to be sought in part in topography, and in part in the structure of the cyclone itself. The former is indicated by the fact above stated, that no matter from what direction the storm approaches New England, or whether the storm is increasing or diminishing in violence, the barometric centre moves ahead in the precipitation area in the few hours it is passing New England. Perhaps the geographical situation of the district with the ocean on the east and south, and land on the north and west, contains the key to the explanation. It would be interesting to know if records in the interior of the country show a similar or an opposite effect. On the other hand, the local topography does not seem adequate to the whole explanation, for the effect is noticed in storms which pass to the coast from the land, as Nos. 48 and 74, in those which skirt along the coast, as Nos. 195 and 196, as well as in those which pass over the hilly interior of New England, as Nos. 46 and 65. We seem to have again evidence of the complicated structure of the cyclone, and of changes in the structure as it moves along, which show themselves in apparent vagaries in the relation of the precipitation to the cyclone. That changes of vital importance to the structure are continually going on is shown by the barometric fluctuations which are frequently noticed during the passage of a cyclone, and which merit more study than they have yet received. To these barometric irregularities we must now add the irregularities in the distribution of the rain and snow over the disturbed area, and also the irregularities in the relation of the precipitation area to the cyclone, which our New England observations show in so marked a degree.

CLASS III.

The main purpose of this investigation was completed with the discussion of the relation of the precipitation areas to the paths of the cyclones, as given in the earlier parts of this paper. In connection with it, however, the precipitation data were noted

in nineteen storms, which were double storms, or which, for some other reason, could not be discussed like the simpler cyclones of Classes I. and II. The following table contains the data for these storms, arranged after the model of Tables XIII.-XVI. The third column gives the pressure for that cyclone, if two are concerned, which was the lower, and which seemed to have the greater influence in the precipitation. The sixth and seventh columns are for the same one also. The descriptions of the individual cases which follow the table are essential to its interpretation.

TABLE XXI.

SECONDARY DEVELOPMENTS, TWO CYCLONES WITH INDEPENDENT PATHS, OR OTHER SPECIAL CASES.

No.	Date of Passage.	Pressure at Centre. (Inches.)	Precipitation.			
			Kind.	Maximum Area.		
				Amount. (Inches.)	Distance from Path. (Miles.)	Direction from Path.
235	Nov. 18, 1886	29.3	Rain and Snow.	3.0	0	—
236	Jan. 6, 1887	29.8	Rain and Snow.	2.4	—	—
237	Jan. 14, "	29.6d	Rain and Snow.	2.5	—	—
238	April 16, "	29.6	Rain and Snow.	0.8	200	NW.
239	Oct. 21, "	29.5	Rain.	2.1	100	NW.
240	Dec. 21, "	29.6	Rain and Snow.	0.8	140	NW.
241	Sept. 1, 1888	29.8	Rain.	2.6	80	NW.
242	Sept. 12, "	29.8	Rain.	1.6	80	NW.
243	Sept. 16-19, "	—	Rain.	5.0	—	—
244	Oct. 12, "	29.7	Rain.	1.0	180	N.
245	Jan. 21, 1889	29.4d	Rain and Snow.	1.5	0	—
246	Jan. 27, "	29.1d	Rain and Snow.	1.2	0	—
247	Nov. 28, "	29.5	Rain and Snow.	4.0	40	SE.
248	Dec. 25, 26, "	29.0d	Rain and Snow.	0.8	140	S.
249	Mar. 21, 22, 1890	29.5d	Rain and Snow.	2.0	160	NW.
250	Oct. 8, "	29.8	Rain.	1.1	—	—
251	Dec. 27, "	29.2d	Snow.	2.5	0	—
252	Nov. 27, 1891	29.3	Rain and Snow.	1.6	0	—
253	Jan. 18, 1892	29.6	Rain and Snow.	1.7	—	—

The nineteen storms of the above table may be grouped as follows: —

1. Those in which a secondary formed while a cyclone was passing, the secondary borrowing the energy from the original cyclone. Examples of this are Nos. 235, 237, 238, 240, 244, 250, and 252.

2. Those in which two independent cyclones passed over or near New England at so nearly the same time that their precipitation areas overlapped.

Examples of this are Nos. 236, 239, 242, 245, 249, and 251, in each of which a cyclone from the lakes and one from the gulf were concerned; No. 246, in which both cyclones came from the gulf, and Nos. 247 and 248, in which both came from the lakes.

3. Those in which a cyclone formed near New England, viz., Nos. 241 and 253.

4. Those in which a cyclone ceased to exist before reaching New England, viz., No. 243, and one of the components of No. 237. We will discuss the storms as thus grouped.

1. *Secondary Cyclones.* 235. While a cyclone was moving northeasterly from Arizona to the lakes, a secondary formed in Pennsylvania. The former continued north of New England, the latter moved across southern Vermont, New Hampshire, and central Maine. The maximum precipitation was in New Hampshire, near the path of the secondary.

237. While a cyclone was moving easterly near Lake Erie, a secondary formed near Connecticut, which crossed that State and Rhode Island. The former lost its independent existence near Vermont, in which the greatest precipitation was noted.

238. While a cyclone was moving north of Lake Ontario, a secondary formed off the New Jersey coast, and moved northeasterly in the ocean, causing the disappearance of the former. The maximum area was in Massachusetts, northwest of the path of the secondary.

240. While a cyclone was moving from Texas to Ohio, a secondary developed off the coast of North Carolina, and moved northeasterly outside of the coast line, the former ceasing to exist.

244. While a cyclone was moving from the gulf along the Atlantic coast, a secondary developed in Indiana, which moved easterly, and united with the former near Cape Cod, the united cyclone continuing its path in the ocean. This is the only case found in which the secondary was developed in any other position than at the *right* of the primary cyclone.

250. While a cyclone was passing from the Indian Territory towards the St. Lawrence Valley, a secondary formed on the Atlantic coast, which moved in the ocean east of New England. The former cyclone ceased to exist in consequence. The rainfall was heaviest on the southern coast, and was apparently increasing towards the path of the secondary.

252. While a cyclone was moving eastward from the lakes towards Maine, a secondary developed off the North Carolina coast, and united with the former in Maine. A third storm followed from south of the lakes, and crossed Vermont, New Hampshire, and Maine a day later. The secondary was the strongest developed cyclone of the three, and the maximum precipitation was along its path.

2. *Two Independent Cyclones.* 236. A cyclone from the lakes moved far north of New England, while a second cyclone was coming up the coast. The latter moved far east of New England, and seems to have sapped the energy of the former. The heaviest precipitation was at Block Island, and was apparently increasing towards the path of the second storm.

239. A cyclone moved eastward north of New England, while a West Indian hurricane was coming up the Atlantic coast. The latter crossed

Rhode Island and eastern Massachusetts. The heaviest rainfall was northwest of the path of the latter, but a secondary maximum occurred in northern Vermont, south of the path of the former.

242. A cyclone which came up the Atlantic on the coast line, on reaching Massachusetts, curved to the north and northwest, and united north of New Hampshire with a second cyclone from the northwest.

245. Both cyclones came from one depression in the Gulf, but one moved first to the lakes and thence southeasterly across northern Connecticut to Rhode Island, where it joined the other which had come up along the coast. The united cyclone continued northeasterly across Massachusetts and along the Maine coast. The heaviest precipitation was near the path of the eastern component.

249. A western cyclone which had come from the Pacific moved far north of New England on the 21st, followed on the 22d by a gulf storm which moved in the ocean east of New England. The precipitation was chiefly due to the latter.

251. A cyclone from the lakes moved southeasterly across Vermont, New Hampshire, and southwestern Maine, while a cyclone coming up the Atlantic crossed Cape Cod and joined the former southeast of the Maine coast. Maximum areas of snow occurred along each of the two paths.

246. Two cyclones came from the Gulf, the former moving northeasterly across northwestern Vermont, northern New Hampshire, and central Maine, the latter across southeastern Massachusetts to eastern Maine, uniting with the former. The heaviest precipitation was near the path of the former.

247. A storm moving northeastward from Texas formed two centres, one of which moved to the lakes and crossed northwestern Vermont, while the latter moved to Connecticut and thence northerly in Vermont till it united with the former, the united storm moving down the St. Lawrence valley. The heaviest precipitation was southeast of the latter path.

248. These two cyclones moved in nearly the same path from the lakes eastward near the northern boundary. The second one was a severe cyclone and followed the other half a day later. The precipitation was quite light.

3. *Developing Cyclones.* 241. A cyclone from the northwest had reached the Lakes and expanded into a large area. In this a centre was formed in Connecticut and moved across Rhode Island and Massachusetts. The rain was heaviest northwest of the newly formed cyclone.

253. An area of high pressure with a very severe cold wave, attended by snow and rain, was advancing towards New England from the lakes. Out of these conditions a cyclone formed south of Long Island and moved rapidly northeastward along the Maine coast. The precipitation was heaviest in Connecticut and Rhode Island north of the region in which the cyclone formed.

4. *Disappearing Cyclones.* 243. Very heavy rains occurred in New England while a cyclone was lingering in Illinois, Indiana, and Michigan. The cyclone broke up without reaching New England.

237. One of the components of this cyclone ceased to exist over Vermont, where heavy snows occurred.

From the data of the table and the above description of the cyclones we may note the following facts (continuing the numbering from the earlier conclusions of this paper): —

19. Storms in which a secondary development occurs usually are near the lakes, the secondary forming off the Atlantic coast and becoming the stronger cyclone.

20. Where two cyclones are passing near New England, the one from the west the other from the south, the latter is usually the stronger cyclone.

21. The precipitation is chiefly the result of the energy of one of the two cyclones, usually the southern one.

22. The maximum areas of precipitation follow the same distribution as previously noted for the single storms of Classes I. and II. Since the precipitation in each case is chiefly due to one of the two cyclones under treatment, the data of the sixth and seventh columns may be regarded as supplementary to the corresponding data under Classes I. and II. Thus Nos. 238, 239, 240, 241, 242, 244, 245, 246, 247, 249, and 252 may be added to Class II., and show three cases in which the precipitation was greatest along the path of the barometric centre, one in which the greatest precipitation was on the right, and seven in which it was on the left of the path at an average distance of 134 miles. This result is in accord with conclusions 15 and 16, the storms above having their paths in some cases over and in others east of New England. Similarly Nos. 235 and 248 may be added to those of Class I., the former having the precipitation along the path and the latter having the maximum area south or on the right of it.

These conclusions are confirmatory of those obtained in the provisional discussion.

23. There are only three of these storms, viz., Nos. 235, 236 and 238, in which data are sufficient to study the movement of the rain front and rear with regard to that of the barometric centre. The results are as follows: —

235. Hourly velocity of rain front 23 miles, of rain rear 30 miles, of barometric centre 60 miles.

236. Hourly velocity of rain front 9 miles, of rain rear 12 miles, of barometric centre, 37 miles.

238. Hourly velocity of rain front 17 miles, of barometric centre, 17 miles.

Therefore in these storms there are two cases in which the barometric centre pushed forward in the precipitation area, and one in which its velocity was the same as that of the rain front.

General Conclusion. The primary purpose of this discussion has been to verify or overthrow the provisional conclusions of the former discussion which were stated at the outset of this paper. It will be seen that those conclusions are verified in every instance, enlarged somewhat, and placed on a strong empirical basis, since they now depend on a large number of

instances. From the twenty-three conclusions derived in the discussion, the following are emphasized as the most important bearing upon the subject of the distribution of precipitation : —

1. The precipitation is sometimes along the path of the cyclone, but in the majority of cases the greatest amount is found many miles away from the path. These maximum areas are at the right or left, or on both sides of the path. The situation of the observing stations is more favorable to showing the maximum areas at the *right* of the paths of storms which come to New England from the west, and at the *left* of those which come from the south; hence these predominate in the cases examined. There is a larger proportion of cases in which the greatest precipitation lies along the track in southern than in western cyclones, and the distances are less in the former class when the maximum area is displaced. (Conclusions 5, 6, 7, 8, 13, 14, 15, 16, 22.)

2. The precipitation area does not maintain a constant position with regard to the barometric centre of the storm while the storm is in transit over New England. While departures from regularity are evidently to be expected in the curve of the rain front and rear as the precipitation area passes over country of varied topography, there seems to be a marked agreement between both rain front and rear in showing a different average rate of progression across New England than that of the barometric centre. In a few cases the rate of the rain front and rear is more rapid than that of the centre, but in the great majority of storms examined the rate was very much less. In other words, the barometric centre is usually displaced forward in the precipitation area while the cyclone is crossing New England. (Conclusions 18 and 23.)

Further study of these two facts should be directed to an examination of cyclones in other parts of the country in order to show how much they are due to the intricate workings of a cyclone itself, and how much to the local situation of New England.

PSYCHROMETER STUDIES.

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IN this JOURNAL, Vol. XI., July, 1894, pages 107 *et seq.*, Prof. H. A. Hazen criticises the theory given by me for the psychrometer, when the wet bulb is covered with ice. Now, in my first paper on this subject,* I have cited and discussed the

* Undersökningar i hygrometri: Akademisk afhandling. Upsala, 1888, page 81 *et seq.* (Researches on Hygrometry. Academical Dissertation.)

explication given by Mr. Hazen of the higher reading of the ice-covered wet bulb, viz., compression of ice.

Firstly. I have repeated the experiment with the two thermometers in a cooled mercury bath, and found, just as Mr. Hazen, that there may be a compression on the ice-covered bulb. For a bulb covered with net lace, and an ice film somewhat thicker than is usually employed, I found a correction for ice compression of —0.06° at —11°, of —0.17° at —25.95°, and of —0.22° at —26.5°, Celsius. When the bulb was covered with an ice film immediately adhering to the bare glass (the bulb being hastily immersed in water, and then cooled, so as to freeze the water three times successively), the correction was found to be —0.32° and —0.47° at —24.45° and —24.95°. Thus, if the ice film is thin, and not adhering immediately to the glass, the compression between —11° and —26° C. will not amount to —0.2°. This correction must, of course, be determined and applied just as Mr. Hazen does.

Secondly. I have protected the wet bulb from compression by covering it with a case of thin copper or glass, having the same form as the bulb, the narrow space between bulb and case being filled with mercury, and the case covered with an ice film as usually. Thus no compression can take place. Notwithstanding, those protected wet bulbs gave higher readings than the dry bulbs, just as the unprotected ones, under the proper weather conditions, and, curiously, they generally read higher than the unprotected. I give here a series of observations of this kind in Upsala.

1888, Feb. 26, 0.30 — 1.0 A. M. The following thermometers were placed in the thermometer screen of the Theovell self-recording apparatus: —

No. 1. A dry bulb thermometer (spherical, 10 mm. diameter).

No. 2. A wet bulb thermometer (same size and form), covered with net lace and ice, unprotected.

No. 3. A protected wet bulb thermometer (cylindrical bulb, length 20 mm., diameter 6 mm.). A case of thin copper plate, separated from the bulb by an interval of ¼ mm., filled with mercury and covered with an ice film protected the bulb.

No. 4. A large wet bulb thermometer (length, 90 mm., diameter, 13 mm., same size as the thermometers of the self-recording apparatus), protected by a copper case, separated by an interval of ½ mm. from the bulb, the interval being filled with mercury.

No. 5. The dry bulb thermometer of the self-recording apparatus.

No. 6. The wet bulb thermometer of the self-recording apparatus (unprotected).

1888. Feb. 26.	Thermometers Corrected for Zero-Point Error.						
	No. 1. dry.	No. 2. ice-cov. unprotect.	No. 3. ice-cov. protect.	No. 4. ice-cov. protect.	No. 5. dry.	No. 6. ice-cov. unprotect.	
h. m.	°	°	°	°	°	°	
3 5 A.	−22.33	−22.15	−21.8	–	–	–	
	–	–	–	−21.55	−22.05	−21.95	Frost fog all this time.
	−22.03	−21.95	−21.5	–	–	–	
	–	–	–	−21.4	−22.0	−21.85	
3 20 A.	−22.33	−22.25	−21.9	–	–	–	
	–	–	–	−21.5	−22.45	−21.9	
	−22.18	−22.1	−21.7	–	–	–	
	–	–	–	−21.45	−22.35	−21.85	
5 0 A.	−23.13	−23.05	−22.9	–	–	–	
	–	–	–	−22.5	−23.25	−22.85	
Mean	−22.40	−22.30	−21.96	−21.68	−22.42	−22.10	

Here the two dry bulbs give the lowest temperature, the means of both being nearly exactly equal. The two ice-covered unprotected wet bulbs give a somewhat higher temperature, the larger instrument reading higher than the smaller. Lastly, the two protected wet bulbs indicate a still higher temperature, the larger giving a higher than the smaller; the larger protected wet bulb reads 0.7° higher than the dry bulbs. The exactness of the instruments was duly tested, the zero point being determined before and after the observations, and found to be unaltered. The dew-point determined by means of Crova's condensation hygrometer (cooling produced by evaporating ethyl chloride) was found at 5 A. M. to be —28° C.* Thus the air was not even saturated with vapor.

Many observations of this kind were made in the following nights, partly with glass cases instead of copper ones. Thus I have proved experimentally that the wet bulb was on these occasions really hotter than the dry bulb, and that the observed difference of temperature was not due to an instrumental error. The heating of the wet bulbs cannot have been caused by radia-

* Perhaps this is somewhat too low on account of some hygroscopicity of the leaden tube serving for aspirating the air.

tion from the surroundings, the snow-covered ground being cooler than the air. The only possible cause I know for this heating is condensation of vapor on the ice. It is seen, also, that this heating is greater the greater is the surface and mass of the bulb. Now, the theory * shows that the psychrometrical difference observed in an unventilated psychrometer is influenced by the dimensions and form of the wet bulb, and though the nature of this influence cannot be determined theoretically, we conclude that the unequal heating must depend on this cause.

Naturally, it will be the best to eliminate the effect of radiation by ventilating the psychrometer, thus, also, making the psychrometer independent of the dimensions and form of the bulb. This remark I have made more than once in my cited paper, and have also used ventilation in some of my experiments, as may be found by studying my papers. I was prevented in the fulfilling of this plan only by want of time, as the cold weather of this winter ceased before the end of these experiments.

Prof. Hazen states (page 109) that one will not find any negative psychrometrical differences between 0° and about — 6.7° C. This statement is erroneous. In my cited paper (page 101) I have given the following observations made in an air saturated with "water vapor" :—

1888. March 30.	Dry Bulb.	Ice Bulb.	Temp. of Enclosure.
9 40 P.	—3.8	—3.65	—3.4
9 50 P.	—3.8	—3.6	—3.4
10 0 P.	—3.8	—3.7	—3.4
Mean	—3.8	—3.65	—3.4

1888. March 31. h. m.	Dry Bulb.	Wet Bulb. Water.	Wet Bulb. Ice.	Temp. of Enclosure.
5 20 P.	—1.33	—1.3	—1.23	—1.0
5 40 P.	—1.3	—1.35	—1.16	—0.9
Mean . .	—1.31	—1.32	—1.19	—0.95

The dry bulb and water bulb readings are nearly exactly equal, whilst the ice bulb readings are 0.15° and 0.12° higher, just as it ought to be according to the theory.

The following series of observations was made under the

* This theory is essentially that given by Maxwell, Stefan, and Ferrel, differing from it only in that respect, that the different properties of "water vapor" and "ice vapor" have been taken in view.

same conditions, except that the air was saturated with "ice vapor": —

1888. March 30.	Dry Bulb.	Wet Bulb. Water.	Ice.	Temp. of Enclosure.
	°			
2 35 A.	−1.1	−1.08	−1.0	−0.55 C.
2 40 A.	−0.85	−1.03	−0.95	−0.45
2 45 A.	−0.8	−0.98	−0.92	−0.4
Mean . .	−0.92	−1.03	−0.96	−0.47

The dry bulb and the ice bulb readings are very nearly equal, whilst the water bulb readings are 0.11° lower, just as it should be.

I found that it was impossible, under these conditions, to cool the water-covered bulb more than 3° C. below zero without bringing it to freezing.

In the same paper (pages 98–100) I have given a series of observations in dry air, the wet bulb being alternately covered with water and with ice. The water then could be cooled to —5.8° C. before freezing. It was found that the psychrometrical difference for water and ice was sensibly the same. This result agrees with that of Prof. Hazen, who states (page 109): "Under these conditions both water and ice give absolutely the same result."

Now supposing this to be true, and granting that the cooling of the wet bulb is caused by its loss of the latent heat absorbed by the evaporation, and that this latent heat is greater for ice than for water, we can prove that the elastic force of water vapor must be greater than that of ice vapor. For, if possible, let the two be equal. Then also the rate of evaporation under the same conditions must be the same from water and from ice, and as the evaporation from ice absorbs more latent heat, the ice-covered bulb must be cooled more than the water-covered, which is contrary to our supposition. Then let, if possible, the elastic force of ice vapor be the greater; it would follow *a fortiori* that the cooling of the ice-covered bulb would be the greater. Thus the elastic force of water vapor must be greater than that of ice vapor.

Prof. Hazen states (see this JOURNAL for June, 1884, page 64) that Regnault's formula for water gives a better result even for an ice-covered bulb than that for ice. Now these two formulæ differ only in that respect, that the former contains the latent heat of water, and the latter that of ice; thus also, if this last statement of Prof. Hazen were strictly true, it would lead to the

absurd conclusion that the latent heat of water and ice should be the same. But, in fact, none of Regnault's formulæ are strictly exact, and the exact formulæ must differ both in respect to the latent heat of evaporation and to the elastic force of vapor.

Prof. Hazen, in agreement with Sworykin, can find no difference between the water bulb and ice bulb psychrometer, because he has never employed saturated air in his experiments. Indeed, the above statement of Prof. Hazen (page 109) can be true only when evaporation takes place at both bulbs. For if the surrounding air be saturated by ice vapor, evaporation will go on only at the water bulb; that will be cooled a little below the air temperature, whilst the ice bulb will maintain the air temperature unaltered. Again, if the air be saturated with water vapor, the water bulb will maintain the air temperature, whilst the ice bulb will be heated a little by the vapor condensation taking place on it. This agrees with my above experiments (pages 9 and 10).

Prof. Hazen, being a most dauntless disbeliever of the well-established propositions of the mechanical theory of heat, says (page 111): "It should be noted that the suggested condensation of water vapor upon the ice, thus liberating latent heat and causing the higher reading, is entirely untenable, even if we grant that there is such a thing as a water vapor in the air and ice vapor near the ice. If such condensation were to go on, there would be a continued accession of ice to the ice bulb, whereas, as a fact, there is a continual diminution of the ice coat."

Now, the fact here spoken of is only a supposition of Prof. Hazen, and the proof is missing. Firstly, it may be remarked that such an accession of ice to the ice bulb cannot be "continual," for it is only in exceptional cases that the air is saturated with water vapor at a temperature below zero, just as it is exceptional that water exists as a liquid at such a temperature. But whenever this exceptional case is to be found, then condensation goes on, so long as the water vapor in the air maintains an elastic force greater than that of the ice vapor.

Some observations made in Spitzbergen and Upsala, though they are not, of course, "absolutely" exact, give a result that seems to prove the fact of condensation in the above case.

Already in Spitzbergen my attention was directed to the fact that there was, often, during several days in the winter, no evaporation at all from the Wild evaporimeter, which was placed in the thermometer shelter and thus protected against precipitation. Thus the observed evaporation was 0.0 mm. from 1882, Dec. 31, 8 P., to 1883, Jan. 3, 12 P., and from 1883, March 13, 3 P., to March 18, 10 A. Moreover, several lectures gave a *negative* evaporation, *i. e.*, condensation, that cannot be explained as caused by a precipitation of snow or hoar frost, as nothing of it was observed during the hours for which the evaporation was negative. Thus for February 26, 1–8 A. there was found an evaporation from the ice in the evaporimeter of —0.2 mm; during these hours most of the ice bulb readings were higher than those of the water bulb by 0.1° to 0.2° C. at a temperature of about —20°. This higher reading may be partly caused by compression of ice, but I do not believe that the whole of it can be attributed to this cause, as the ice film on the muslin covering was always very thin; and as I have shown by the above-cited experiments in Upsala even an ice film, thicker than usual and applied on a very thin net lace covering, gave only a compression of —0.17° at —25.95°. As I had not suspected such an ice compression before I read Prof. Hazen's paper on it after my return from Spitzbergen, I have made no determinations of it at the polar station.

At Upsala, in March, 1888, I made some experiments to prove directly the condensation of vapor on a cylindrical glass bulb (about 90 mm. in length, 13 mm. in diameter) covered with an ice coat, by weighing it before and after its exposure. The difficulties, however, of such an experiment, are very great. The changes of weight were extremely small and all the operations must be performed in the winter cold, at about —25° C., the balance being placed in the entry of the meteorological observatory at open doors. The change of weight was but some milligrams, after the bulb had been hanging during two or three hours in a temperature between —20° and —30° C. Twice I really got an increase of weight of 2 and 3 mg. The bulb hanging by a little glass hook bent at its upper end was suspended by means of pincers, on a hook of copper wire in the balance, weighed, then suspended for two or three hours in the free air, brought in the balance and weighed again.

As to the existence of "such a thing as a water vapor in the air and ice vapor near the ice," I take the liberty of recommending to Prof. Hazen the study of the works of the following eminent physicists and skilful experimenters, who all agree that there is such a thing: —

Kirchhoff, Pogg. Ann. 103, p. 206 (1858);

James Thomson, Report of the British Association for the Advancement of Science, 1871, Transactions of the Sections, p. 30, 1872, Transactions of the Sections, p. 24, Proceedings of the Royal Society of London, Vol. 22 (1874), p. 27;

W. Ramsay and S. Young, Philos. Transactions, Vol. 175 (1884), p. 461;

W. Fischer, Wiedemann's Ann. Band 28 (1886), p. 400;

J. Juhlin, Bihang till K. Svenska Vet.-Akad. Handlingar. Band 17. Afd. I. No. 1. (Swedish, reported briefly in Meteorologische Zeitschrift, 1894, p. 98, and in Beiblätter zu Wied. Ann., Band 18. Stück 7, p. 736) (1894).

All these physicists, partly theoretically by means of the mechanical theory of heat, partly by experiments of different methods, agree in finding, within the limits of errors of observation, the same values for the elastic force of water vapor and of ice vapor, the former being greater than the latter by some tenths of millimeters at the same temperature below freezing.*

Furthermore, Prof. Hazen states the following "fact": "Nearly all the difficulty found in using the wet and dry bulb thermometers vanishes when they are well ventilated, and this is pre-eminently the case at temperatures below freezing, or with ice on the wet bulb."

Now, of course, I fully agree on the great advantage of the ventilated psychrometer, and, as mentioned above, I had begun to use it occasionally in Spitzbergen. But, as shown above, it does not eliminate the difficulty of negative psychrometrical differences, which, as far as they are real and not due to an instrumental error, such as compression of ice, are fully explained by the properties of water vapor and ice vapor. It should be remarked, that such negative differences have been observed with Assmann's aspiration psychrometer in balloon

* Juhlin's tables extending from —20° to +20° C. for water vapor and from —50° to 0° C. for ice vapor, should be reprinted in this JOURNAL.

ascents during the last years here in Sweden and in Germany. They are to be found also between zero and —6.7° C., and are too great to be explained by ice compression.

Secondly, in these balloon ascents there have been observed several times so great psychrometrical differences in a dry and rarefied air (at about 500 mm. barometric pressure and a temperature about —6° to —9° C.), that the ordinary formula (that of Sprung) gives negative humidity. This peculiarity is yet unexplained; the explanation proposed by me has not yet been controlled by experiments.*

Lastly, I must remark that it seems to me very curious to wet a psychrometer with a mixture of water and alcohol, for the evaporation of alcohol must necessarily make the observation erroneous.

I think the only reliable means of protecting the wet bulb from ice compression will be to put around it a thin case filled with mercury, and apply the ice to it, just as I have done. If this case be made of platinum it could be very thin, so that the conduction of heat would be but little prevented by it.

METEOROLOGICAL RECORDS OBTAINED IN THE UPPER AIR BY MEANS OF KITES.

H. HELM CLAYTON.

THE desirability of obtaining meteorological records at altitudes above the earth's surface is now universally admitted. Heretofore our fragmentary knowledge of what is to be found in the upper air has been confined mainly to observations taken in balloons and at mountain observatories; but expense, danger, and other obvious reasons have prevented general and systematic observations being obtained by these means.

Mr. E. Douglas Archibald, of England, was probably the first to attempt observations by means of kites. He succeeded in sending up anemometers and obtaining records of wind velocity up to altitudes of about two thousand feet.

Later Mr. William A. Eddy, of Bayonne, N. J., took up the

* Am psykrometerformeln, särskildt vid laga lufttryck. Öfvers. K. Vet. Akad. Handl. Stockholm, 1894.

subject with enthusiasm and has made his name well known in this connection. His first efforts were directed toward improving the kite, and he has evolved a kite of the Malay type (a kite without a tail), which ascends easily and flies with comparative steadiness.

After developing the kite he undertook to reach great altitudes with it. To do this he adopted the method of flying the kites tandem. He sends up a kite a short distance and then ties the end of its string to the main line which is already supported by one or more kites. He lets out the main line for an interval and then ties to it the string of another kite and so on, thus obtaining a long line of kites with their combined lifting power. In this way he has sent up kites according to his measurements at Bayonne to altitudes exceeding a mile.

During the present summer he came to Blue Hill Observatory for the purpose, if possible, of sending up self-recording instruments and attaining great altitudes. (He had already succeeded in sending up a minimum thermometer.)

Mr. S. P. Fergusson, of this observatory, remodelled for this purpose a small Richard thermograph. The heavier parts were replaced by aluminum, the recording parts arranged in a smaller space, and hard rubber used for the base so that the total weight when completed was only one pound eight ounces, the original weight being eight pounds.

On August 4, Mr. Eddy sent up three kites tandem, one seven feet, and two four feet in length, and at the intersection of the cord from the last kite with the main line the thermograph was tied on. Cord was let out and three more kites, two six feet and one nine feet in length were added successively, which rapidly lifted the thermograph above the earth's surface.

For obtaining altitudes a base line of 360 feet was laid off in the line of the kites, and simultaneous readings of the angular heights of the thermograph were made at each end by means of two boards divided into degrees and fitted with sights, and a plumb line for determining the departure from the vertical. The altitudes were calculated by one of the following formulas:

$$Z = \frac{b}{\cot h_1 - \cot h_2}, \text{ or } Z = b\ (b \pm c \cot h_2)\ \frac{\sin h_1 \sin h_2}{\pm \sin (h_2 - h_1)}$$

in which Z is the altitude, b the base line, h_1, and h_2 the two angles, and c the amount of inclination of base line from hori-

zontal, the + or — sign being used according to the direction of inclination of the base. In our measurements *c* was small and was neglected.

The thermograph left the earth's surface at 2.05 P. M., and angular measurements of its altitude were made at short intervals which appear below. The sky was cloudy and at first the thermograph was sent up with only a small sheet of aluminum arched over the bulb for a screen; but after 3.10 P. M., the sun came out and the thermograph was hauled down for inverting over it a light basket weighing ten ounces which served very well as a shelter. At 4.04 P. M. the thermograph was again elevated, and by 4.37 P. M. reached an altitude above the hill top exceeding 1,000 feet. At 5.15 P. M. hauling in the kites was begun and the thermograph reached the earth at 5.50 P. M., bringing back a successful record. While the kites were in the air the wind was from W. and N.W. with a velocity gradually rising from ten miles at the beginning to twenty miles at the end of the experiment. The barometer was rising, a minimum having occurred during the preceding night. The sky had been clouded during the morning with strato-cumulus surmounted by a sheet of alto-stratus, but these began to break away about two P. M., though the sky continued more than half covered. The temperature recorded by a thermograph at the Blue Hill Valley Station, fifty feet above sea level, and two miles north of the Observatory, that recorded by a similar thermograph at the Observatory 640 feet above sea level, that recorded by the kite thermograph, and the altitudes of the latter are given below. In determining the altitudes in each case, five or more successive angular measurements were made simultaneously at each end of the base line; and the altitudes given in each case are the means of three or more altitudes computed from the best observations. For comparison with the Observatory thermograph the kite thermograph was suspended in the open air near the former for a short while preceding 2.05 P. M., and 4.04 P. M., and after the experiments it was placed in the shelter with the Observatory thermograph. The mean difference between the two was used as a correction for the aerial thermograph. The Observatory and Valley Station thermographs were controlled and corrected by readings of standard thermometers. The cylinders on the Observatory and kite thermographs turn once

a day, giving a time scale of about one centimeter an hour. The Valley Station thermograph has a weekly cylinder.

Observed Temperatures and Altitudes, Aug. 4, 1894.

First Ascent.

Time, P. M.	2:05	2:22	2:41	3:08	3:10
Valley Station, alt. 50 feet	67.4°	68.3°	69.0°	71.2°	71.7°
Observatory, alt. 640 feet	66.0°	65.9°	66.8°	69.2°	69.4°
Kite Thermograph	66.0°	63.2°	63.4°	64.7°	64.7°
Altitudes above sea, feet	640	828	977	1,138	1,355

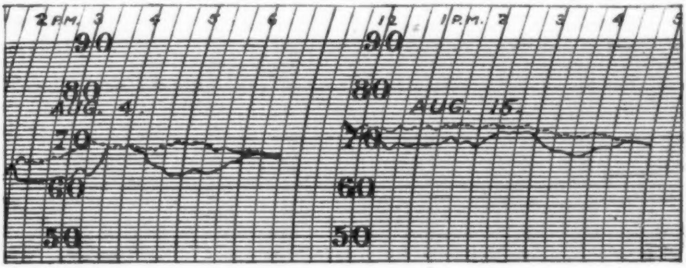
	Second Ascent.						*Evening.*	
Time, P. M.	4:04	4:37	4:54	5:03	5:05	5:50	6:15	8:00
Valley Station, alt. 50 feet	71.3°	71.4°	72.3°	72.3°	72.2°	70.2°	68.5°	63.5°
Observatory, alt. 640 feet	69.0°	69.1°	69.7°	69.4°	69.9°	67.7°	68.0°	64.0°
Kite Thermograph	70.3°	65.8°	64.1°	64.3°	64.4°	66.7°	67.8°	63.9°
Altitudes above sea, feet	640	1,642	Max.	2,070	1,720	640	640	640

On Aug. 15, with the assistance of Mr. John Ritchie, Jr., the thermograph was again sent up. The same precautions were taken as in the previous case, and the following notes were made at the time. "After letting up two kites the thermograph was attached and left the earth at 11.46 A. M. Two additional kites were added in succession and rapidly lifted the thermograph. From 12.20 P. M. to 1.30 P. M. the thermograph remained nearly stationary at a considerable altitude. Five simultaneous angular measurements made at the end of the 360-foot base line gave the following altitudes above the hill top: 492 feet, 400, 472, 403, 413, — mean 436 ± 37. More cord was let out and at 1.52 P. M. the angular measurements gave the following altitudes of the thermographs: 521, 617, 677. The kites were visibly rising at this time and hence no mean was taken. The last altitude is considered the most accurate. At 2.20 P. M. the thermograph was lowered to within about 200 feet of the earth's surface for repairs to one of the kites. It was elevated again at 2.47 P. M. and rose rapidly to its maximum altitude. Between 3.28 and 3.39 P. M. four angular measurements gave the following altitudes: 1,010 feet, 820, 860, 888, — mean of last three 856 ± 24. After the first angular measurement was obtained the lower kite dived and drew the others down so that the first altitude given is probably correct. At 3.40 P. M. lowering the kites was begun. At 4.03 P. M. angular measurements gave the altitudes of the thermograph as 395 feet; at 4.18 P. M., 522 feet; at 4.20 P. M., 192 feet, and at 4.26 P. M., it reached the surface of the hill. The thermograph was

then placed in the thermometer shelter for comparison with standards."

OBSERVED TEMPERATURES AND ALTITUDES, AUG. 15, 1894.

Time.	11:46 A. M.	1:30 P. M.	1:52	3:28	3:30
Valley Station, alt. 50 feet	78.0°	77.4°	77.4°	73.8°	73.8°
Observatory, alt. 640 feet	72.6°	72.7°	72.9°	71.1°	71.0°
Kite Thermograph	72.4°	72.2°	71.0°	67.5°	67.6°
Altitudes above sea, feet	640	1,076	1,317	1,650	1,496
Time.	4:03 P. M.	4:18	4:20	4:26	6:00
Valley Station, alt. 50 feet	74.1°	72.7°	72.5°	72.2°	68.7°
Observatory, alt. 640 feet	71.3°	70.3°	70.1°	70.0°	66.0°
Kite Thermograph	69.3°	69.4°	69.6°	70.0°	66.0°
Altitudes above sea, feet	1,035	1,162	832	640	640



Broken Curve is traced from Observatory Thermograph.
Continuous Curve is traced from Kite Thermograph.

During this experiment the wind blew steadily from the south with a nearly constant velocity of about twenty miles an hour. The barometer was falling slowly and reached a minimum during the night. The sky was covered with alto-cumulus and alto-stratus increasing in density, and it became necessary to draw down the kites on account of the approach of a thunder-shower from the west which reached the observatory at 5.14 P. M.

Copies of the records made by the Observatory and kite thermographs are given in the accompanying cut.

To study the rate of decrease of temperature with altitude the following tables were constructed: —

RATE OF DECREASE OF TEMPERATURE PER 100 FEET, AUG. 4, 1894.

Time.	2:22 P. M.	2:41	3:08	3:10	4:37	5:03	5:05
Valley to Summit	0.41°	0.37°	0.34°	0.39°	0.39°	0.49°	0.39°
Summit to Kite	1.43°	1.01°	0.90°	0.66°	0.33°	0.36°	0.50°

AUG. 15, 1894.

Time.	1:30 P. M.	1:52	3:28	3:30	4:03	4:18	4:20
Valley to Summit	0.80°	0.76°	0.46°	0.47°	0.47°	0.41°	0.41°
Summit to Kite	0.14°	0.28°	0.36°	0.40°	0.51°	0.18°	0.26°

These results may be summarized as follows: —

RATE OF DECREASE OF TEMPERATURE PER 100 FEET.

	Aug. 4, 1894. First Ascent.	Aug. 4, 1894. Second Ascent.
Valley to Summit — Mean . .	(4 obs.) 0.38°	(3 obs.) 0.42°
Summit to Kite — Mean . . .	do. 0.97°	do. 0.40°

Aug. 15, 1894.

Time.	1:30–2 P. M.	3:28–3:30	4:03–4:20
Valley to Summit — Mean . .	(2 obs.) 0.78°	(2 obs.) 0.47°	(3 obs.) 0.43°
Summit to Kite — Mean . . .	do. 0.21°	do. 0.38°	do. 0.32°

Or, beginning at the valley station and taking the temperatures recorded at the approximate levels given below, the following results are obtained: —

RATE OF DECREASE OF TEMPERATURE PER 100 FEET.

Aug. 4, 1894. Altitude above Valley.	Aug. 15, 1894. Altitude above Valley.
600 feet (7 obs.) 0.40°	600 feet (7 obs.) 0.54°
1,200 feet (2 obs.) 0.56°	1,100 feet (3 obs.) 0.40°
1,800 feet (3 obs.) 0.40°	1,500 feet (3 obs.) 0.42°

A study of the individual results given in the first table shows that on Aug. 4 the temperature decreased rapidly for a short distance above the hill and then more slowly, while on Aug. 15 the reverse of this was true. What relation this has to wind and weather will have to be determined by future observations, but the results on the two days are interesting from the fact that the first were obtained immediately in the rear of a barometric minimum and the second immediately in front. The last table shows that the mean decrease of temperature from the valley station to the highest points reached was almost exactly the same in each case and was at the rate of 1.2° Fahr. for each 300 feet of ascent, or .73° C. for 100 meters.

Several other interesting results were furnished by Mr. Eddy's kites.

On July 31 the kites were let up at noon in a sea breeze. When the kites had risen about 400 feet above the hill the topmost kite veered around from the west, thus giving the depth of the sea breeze as 1,000 feet above sea level. During the afternoon the sea-breeze steadily increased in depth and veered toward the south.

On Aug. 6, during the prevalence of light winds from the west, an effort was being made to elevate the kites which refused

to remain permanently in the air since the air movement was not sufficient to sustain the heavy kites employed. But at 2.20 P. M., while a five-foot kite was being maintained at a short distance above the hill by means of sundry jerks and pulls, a rather large cumulus cloud approached the zenith, and suddenly the kite began to ascend almost vertically. Cord was rapidly let out and in a short time the kite was flying directly overhead, and continued to rise until all the available cord had been let out. It followed the cumulus for a short distance beyond the zenith, then rapidly dropped to the earth. Mr. Eddy afterward measured the length of cord out and reported 1,172 feet, which must have been approximately the altitude of the kite since the cord hung almost vertically under it. This seems to furnish striking evidence of the existence of ascending currents under the cumulus clouds.

The kites also at times gave evidence of great ærial eddies around and above the hill which swayed the kites from side to side.

It is hoped to continue these experiments at the Blue Hill Observatory, and if possible reach great altitudes. Mr. S. P. Fergusson believes he can construct a meteorograph which will record pressure, temperature, wind velocity, and humidity, and not be beyond the lifting power of the kites.

For the benefit of those who may wish to try experiments elsewhere, it may be mentioned that a picture of Mr. Eddy's kites, the method of flying them, and a picture of the thermograph sent up at Blue Hill will be found in the *Scientific American* of Sept. 15, 1894.

MEETING OF THE INTERNATIONAL METEOROLOGICAL COMMITTEE.

A. LAWRENCE ROTCH.

THE meetings were held at the University of Upsala, Aug. 20 to 24, 1894, and were attended by the following members of the Permanent Committee: Prof. von Bezold of Prussia, Director Billwiller of Switzerland, Mr. Davis of the Argentine Republic, Prof. Hann of Austria, M. Hepites of Roumania, Prof. Hildebrandsson of Sweden, Prof. Mascart of France, Prof.

Mohn of Norway, Dr. Paulsen of Denmark, Mr. Scott of England, Dr. Snellen of Holland, and Prof. Tacchini of Italy.

The absent members were Admiral de Brito Capello, Messrs. Eliot and Ellery, Prof. Harrington, and Director Wild, the president.

On account of the absence of the latter, M. Mascart presided. Mr. Scott, as secretary, submitted a brief report, with the questions proposed for discussion. A statement of them with the decisions follows: —

International Bureau. A report was presented by Prof. Hildebrandsson, in which the functions and cost of such a bureau were considered. The committee decided against its establishment.

Agricultural Meteorology. Prof. Harrington has been unable to submit his report, but Mr. Scott's proposition was adopted, that the methods employed to distribute weather predictions to farmers and the results of climatological discussions relating to the crops in the various countries be published.

Establishment of Stations for Cloud Observations. Prof. Hildebrandsson has not furnished the detailed instructions, proposed at Munich, but with the aid of Messrs. Hagström and Åkerblom he has given in a pamphlet a detailed account of the principal methods employed in these investigations.

The committee adopted these resolutions: —

Since experience shows that the altitude of clouds can be easily determined with sufficient accuracy, the generalization of these investigations in all countries is recommended, preferably by the use of the photographic process. Observations of direction and relative velocity should be made at as many stations as possible and measures of height at a limited number of suitably distributed stations.

The value of these investigations would be greatly increased, if made at the same epoch, therefore it is proposed that they be commenced May 1, 1896, and continued for one year.

The stations already promised are these: —

Batavia, one station with theodolites.

France, one station with photogrammeters.

Norway, one station with theodolites and photogrammeters.

Portugal, one station with photogrammeters.

Prussia, one station with photogrammeters.

Roumania, one station with photogrammeters.

Russia, two stations with photogrammeters.

Sweden, one station with photogrammeters.

United States: Blue Hill, one station with theodolites and photogrammeters; Weather Bureau, six stations for observation of direction and relative velocity.

Cloud Atlas. The committee appointed at Munich has been enlarged by the co-optation of Profs. Mohn and Riggenbach. This committee reported slightly modified definitions of some types in the Hildebrandsson-Köppen-Neumayer Atlas, and submitted photographs and pastels for reproduction in the new atlas as well as instructions for observing clouds. These were adopted by the Permanent Committee after discussion and modification. (See Appendix.) A special committee, composed of M. Teisserenc de Bort and Prof. Riggenbach, with Prof. Hildebrandsson as chairman, was appointed to publish the atlas, and the choice of the color of each plate to represent as nearly as possible the natural conditions, was left to its discretion.

More Rapid Transmission of Telegrams. Dr. Snellen presented a joint report with Dr. Neumayer on this question, in which the necessity of giving the meteorological despatches precedence over others, by opening a circuit system with the other central bureaus, was urged. The introduction of simultaneous observations in the various countries was deemed necessary. The committee referred the matter to the International Telegraphic Bureau at Berne.

In more or less intimate relation with this question, was a proposition by Dr. van Bebber on the importance of further experiments in tele-meteorography. Dr. Snellen explained the telegraphic transmission of the traces of self-recording instruments by the Olland apparatus, which operates over a short distance at Utrecht.

Scintillation of Stars. At the request of M. Ch. Dufour, this question, which had been the object of investigations by M. Montigny, of Brussels, was brought before the committee. Further study by him, together with that of M. Ventosa on the atmospheric movements observed around stars, was encouraged.

Maritime Meteorology. A proposition of the Russian Admiral Makaroff, on the necessity of an international convention

to arrange for the discussion of the data contained in ships' logs, was not approved.

Psychrometric Observations below Freezing. This question was introduced by Profs. Hildebrandsson and Mohn. The employment of Ekholm's method for the reduction of mean values was recommended, but a report of further investigations was requested.

Exploration of Upper Air. A resolution received from the *Congrès de la Science de l'Atmosphère,* which had recently met in Antwerp, on the importance of the balloon ascents, now being made at Berlin, for meteorological purposes, was confirmed in a more general sense.

Next Congress. It was decided to convene a non-official Congress at Paris in September, 1896.

APPENDIX.

The Committee on the Cloud Atlas held its meetings at the same time and place as the Permanent Committee. All the members were present, viz.: Prof. Hann, Prof. Hildebrandsson, Prof. Mohn, Prof. Riggenbach, Mr. Rotch, and M. Teisserenc de Bort. The other meteorologists at Upsala were invited to attend the meetings; besides the members of the Permanent Committee there were: Prof. Broounof, of Kieff, Drs. Fineman and Hagström, of Upsala, Prof. Sprung, of Potsdam, and M. Weilbach, of Copenhagen. Prof. Hildebrandsson and M. Teisserenc de Bort presided successively, and Prof. Riggenbach was the secretary.

In the cloud classification of Hildebrandsson and Abercromby, published in the Hildebrandsson-Köppen-Neumayer Atlas, in 1890, the word "diurnal" is added to the definition of Group D, so that it becomes:—

D. Clouds formed by the diurnal ascending currents.

In this way, the cumulus arising from a mass of aqueous vapor ascending through calm air is distinguished from the nimbus caused by the general ascension of the whole mass of moist air.

With this change the classification of the ten principal forms is:—

a. Detached or rounded forms (most frequent in dry weather).
b. Wide-spread or veil-like forms (wet weather).

A. Highest clouds, mean height 9,000 meters.
a. 1. Cirrus.
b. 2. Cirro-stratus.

B. Clouds of mean altitude, 3,000 — 7,000 meters.
a { 3. Cirro-cumulus.
4. Alto-cumulus. }
b. 5. Alto-stratus.

C. Low clouds, 1,000—2,000 meters.*
a. 6. Strato-cumulus.
b. 7. Nimbus.

D. Clouds formed by the diurnal ascending currents.
8. Cumulus. Top, 1,800 meters; base, 1,400 meters.
9. Cumulo-nimbus. Top, 3,000 — 5,000 meters.* Base, 1,400 meters.

E. Elevated fog, below 1,000 meters.
10. Stratus.

N. B. As the heights of the clouds marked * do not agree with the heights of these clouds found at Blue Hill, the writer has asked that the altitude of the low clouds be placed below 2,000 meters simply, instead of between 1,000 and 2,000 meters, since the bases of nimbus are frequently below 1,000 meters; and also that the superior limit of the tops of the cumulo-nimbus be raised to 8,000 meters.

Descriptions of the Clouds (modified from those in the Hildebrandsson-Köppen-Neumayer Atlas).

1. CIRRUS (Ci.). *Isolated feathery clouds of fine fibrous texture, generally of a white color.* Frequently arranged in bands which spread like the meridians on a celestial globe over a part of the sky and converge in perspective towards one or two opposite points of the horizon. (In the formation of such bands Ci. S. and Ci. Cu. often take part.)

2. CIRRO-STRATUS (Ci. S.). *Fine whitish veil,* sometimes quite diffuse, giving a whitish appearance to the sky, and called by many cirrus haze, sometimes of more or less distinct structure, exhibiting confused fibres. The veil often produces halos around the sun and moon.

3. CIRRO-CUMULUS (Ci. Cu.). Fleecy cloud. *Small white balls and wisps without shadows, or with very faint shadows, which are arranged in groups and often in rows.*

4. ALTO-CUMULUS (A. Cu.). Dense fleecy cloud. *Larger whitish or grayish balls with shaded portions, grouped in flocks or rows, frequently so close together that their edges meet.* The different balls are generally larger and more compact (passing into S. Cu.) towards the centre of the group, and more delicate and wispy (passing into Ci. Cu.) on its edges. They are very frequently arranged in stripes in one or two directions.

(The term cumulo-cirrus is given up as causing confusion.)

5. ALTO-STRATUS (A. S.). *Thick veil of a gray or bluish color*, exhibiting in the vicinity of the sun and moon a brighter portion, and which, with out causing halos, may produce coronæ. This form shows gradual transitions to cirro-stratus, but according to the measurements made at Upsala, has only half the altitude.

(The term stratus-cirrus is abandoned as giving rise to confusion.)

6. STRATO-CUMULUS (S. Cu.). *Large balls or rolls of dark cloud which frequently cover the whole sky, especially in winter*, and give it at times a wavelike appearance. The stratum of strato-cumulus is usually not very thick, and blue sky often appears in the breaks through it. Between this form and the alto-cumulus, all possible graduations are found. They are distinguished from nimbus by the ball-like or rolled form and because they do not tend to bring rain.

7. NIMBUS (N). Rain clouds. *Dense masses of dark formless clouds with ragged edges*, from which generally continuous rain or snow is falling. Through the breaks in these clouds there is almost always seen a high sheet of cirro-stratus or alto-stratus. If the mass of nimbus is torn up into smaller patches, or if smaller clouds are floating very much below a great nimbus, the former may be called Fracto-nimbus ("Scud" of the sailors).

8. CUMULUS (Cu). Piled clouds. *Thick clouds whose summits are domes with protuberances but whose bases are flat.* These clouds appear to form in a diurnal ascensional movement which is almost always apparent. When the cloud is opposite the sun the surfaces which are usually seen by the observer, are more brilliant than the edges of the protuberances. When the illumination comes from the side this cloud shows a strong actual shadow; on the sunny side of the sky, however, it appears dark with bright edges. The true cumulus shows a sharp border above and below. It is often torn by strong winds and the detached parts (Fracto-cumulus) present continual changes.

9. CUMULO-NIMBUS (Cu. N.). Thunder cloud; shower cloud. *Heavy masses of clouds, rising like mountains, towers, or anvils, generally surrounded at the top by a veil or screen of fibrous texture* ("false cirrus") *and below by nimbus-like masses of cloud.* From their base generally fall local showers of rain or snow, and sometimes hail or sleet. The upper edges are either of compact cumulus-like outline, and form immense summits, surrounded by delicate false cirrus, or the edges themselves are drawn out like cirrus. This last form is most common in "spring squalls." The front of storm clouds of great extent sometimes shows a great arch stretching across a portion of the sky which is uniformly lighter in color.

10. STRATUS (S.). *Lifted fog in a horizontal stratum.* When this stratum is torn by the wind or by mountain summits into irregular fragments they may be called Fracto-stratus.

Illustrations of the Clouds.

The photographs chosen to represent these types of clouds were by Riggenbach, of Bâle; Sprung, of Potsdam; Neuhauss, of Berlin; Garnier, of Paris; Clayden, of Exeter (England); Fergusson, of Blue Hill; Henry and McAdie, of Washington,

and Child & Co., of Newport, R. I. (U. S. A.). Some of the pastels of Weilbach, of Copenhagen, and two of the lithographs in the previous atlas were also selected for the new atlas. As explanatory illustrations in the text, to represent wave motion in clouds, the following two photographs were chosen: —

Cirrus of Raymond, representing simple undulations.
Cirro-cumulus of Riggenbach, representing double undulations.

The colored plates are thus composed: —

For cirrus, four illustrations are to be given.
Cirro-stratus, one illustration is to be given.
Cirro-cumulus, one illustration is to be given.
Alto-cumulus, two illustrations are to be given.
Alto-stratus, one illustration is to be given, made up of two halves.
Strato-cumulus, one illustration is to be given.
Nimbus, one illustration is to be given.
Cumulus, two illustrations are to be given.
Cumulo-nimbus, three illustrations are to be given.
Stratus, one illustration is to be given.
Fracto-stratus, one illustration is to be given.
Fracto-cumulus, two illustrations are to be given.
Mammato-cumulus, one illustration is to be given.

Instructions for Observing Clouds.

At each observation there are to be recorded: —

1. *The Kind of Cloud,* designated by the international letters of the cloud name, which may be more exactly defined by giving the number of the picture of the Atlas most nearly representing the observed form. (Example C 3.)

2. *The Direction from which the Clouds Come.* — If the observer remains completely at rest during a few seconds, the motion of the clouds may be easily observed relatively to a steeple or mast erected in an open space.† If the motion of the cloud is very slow the head must be supported. Clouds should be observed in this way only near the zenith, for if they are too far away from it the perspective may cause errors. In this case nephoscopes should be used and the rules followed which apply to the particular instrument employed.

3. *Radiant Point of the Upper Clouds.* — These clouds often appear in the form of fine parallel bands, which, by an effect of perspective, seem to come from one point of the horizon. The radiant point is that point where these bands, or their direction prolonged, meet the horizon. The position of this point on the horizon should be recorded in the same way as the wind direction, N, NNE, etc.

† M. Broounof proposes, as a very convenient method, the use of a mast having two cross bars placed S — N and E — W.

4. *Undulatory Clouds.* — It often happens that the clouds show regular, parallel and equi-distant streaks, like the waves on the surface of water. This is the case for the greater part of the cirro-cumulus, strato-cumulus (roll-cumulus), etc. It is important to note the direction of these streaks. When there are apparently two distinct systems, as is to be seen in clouds separated into balls by streaks in two directions, the directions of the two systems should be noted. As far as possible, observations should be made on streaks near the zenith to avoid effects of perspective. Examples. . . .

5. *Density and Position of Cirrus Banks.* — The upper clouds frequently take the form of felt or of a more or less dense veil, which, rising above the horizon, resembles a thin white or grayish bank. As this cloud form has an intimate relation to barometric depressions, it is important to note: —

(*a*) The density, —
0 meaning very thin and irregular.
1 meaning thin but regular.
2 meaning rather dense.
3 meaning dense.
4 meaning very dense and of dark color.
(*b*) The direction in which the veil or bank appears densest.

Remarks. All interesting details should be noted, for example: —

1. On summer days all low clouds generally assume particular forms resembling cumulus more or less. In this case there should be put under *Remarks*, "Stratus or Nimbus Cumuliformis." (Fig. —.)

2. It sometimes happens that a cumulus has a mammillated lower surface. This appearance should be described by the name of "Mammato-cumulus." (Fig. —.)

3. It should always be noted whether the clouds appear stationary or whether they have a very great velocity.

The text of the Atlas is to be in French, English, and German. Translations into other languages should be made under the supervision of the Publication Committee; consequently, the right to publish translations will be reserved.

CURRENT NOTES.

Meteorology at the British Association. — The Oxford meeting had little of strictly meteorological interest, which led the London *Times* to observe: "Of all the departments under this section (Mathematics and Physics), that of Meteorology received least encouragement. The numerous reports of work done on Ben Nevis and elsewhere showed that we are holding our own, but compared with present activity in America and on the Continent, British meteorology was distinctly deficient."

The reports of committees thus referred to were those presented annually on Solar Radiation, Underground Temperature, Underground Waters, Ben Nevis Observatory, Earth Tremors, Volcanic Phenomena of Vesuvius, Climatology of Tropical Africa, and Meteorological Photography. With the exception of the last, these reports contained nothing of very general interest, but in view of the recommendation to use photographic methods for cloud measurements by the International Meteorological Committee at its Upsala meeting, the following extract from the last-mentioned report, drawn up by Mr. A. W. Clayden, is interesting: "In the course of experiments on cloud photography it has been found easy to secure well-defined images of clouds even when the sun is in the middle of the field of view. If then two such photographs are taken simultaneously by a pair of cameras at some distance apart, there will be a displacement of the image relatively to that of the sun. The amount of this displacement will depend upon a number of things, but it will be increased by adding to the focal length of the lens, and by increasing the distance between the cameras. By knowing these values and the altitude and azimuth of the sun, the distance of the cloud and its height above the ground may be calculated without difficulty. The azimuth and altitude of the sun at the time of exposure may be ascertained by direct observation, or it may be found by calculation from the known time at which exposure was made. There seems to be a manifest advantage in thus using the sun as a fixed point of reference, and it provides a means whereby any error in the observation of altitude or azimuth may be effectively checked. A pair of cameras are so constructed as to be easily directed towards the sun. They are provided with lenses of eighteen inches focus, covering a plate of whole-plate size, thereby giving a large displacement and allowing room for a displacement of several inches. The lenses are provided with adjustable shutters which can be simultaneously freed by an electrical attachment. They are placed on stands which serve as cupboards for them when not in use. At present, for purely trial purposes, they are placed in a garden at a distance of 35 yards, yet even that short distance gives a displacement of half an inch with clouds 3,780 feet distant.

This, of course, is too small for very accurate measurements, and would be far smaller with high level clouds, the determination of whose altitude is most important. It is the intention to place the cameras on level ground about a quarter of a mile apart in an east and west direction, thereby greatly simplifying the reduction of the observations. The method is easy to apply, and promises to yield results at least as accurate as any which have yet been tried."

There were two interesting presidential addresses in departments of science bordering on meteorology. Prof. A. W. Rücker spoke to the Mathematical and Physical Section on "Terrestrial Magnetism," discussing the errors of magnetic instruments, the magnetic condition of the earth, and the causes of disturbances, while Capt. W. J. L. Wharton, hydrographer to the Admiralty, the president of the Geographical Section, devoted his address to a "Survey of our Knowledge Concerning the Sea," though his data were not always the most recent. The sensation of the meeting was the announcement to the Chemical Section, by Lord Rayleigh and Prof. Ramsay, of the discovery of a new gas in the atmosphere. Attention was first called to this substance by the fact that the density of nitrogen obtained from atmospheric air differed about one-half per cent from the density of nitrogen obtained from other sources. It has been found that, after all the oxygen and all the nitrogen have been removed from a quantity of pure, dry air, a residue is left, amounting to nearly one per cent of the whole, which has a density greater than that of nitrogen, and gives a spectrum with a single blue line much more intense than a corresponding line in the nitrogen spectrum. Whether this new substance be an element or not and what its physical and chemical properties may be remains to be seen; but notwithstanding the chemical inertness which has enabled it to escape observation so long, and which makes further research extremely difficult, its discovery can hardly fail to produce profound effects in the whole circle of sciences. A. L. R.

Death of Mr. Charles Carpmael. — Charles Carpmael, M. A., F. R. A. S., director of the Meteorological Service of Canada, died at Hastings, England, on Oct. 20, 1894.

BIBLIOGRAPHICAL NOTES.

REPORT OF THE CHIEF OF THE WEATHER BUREAU FOR 1893.

MARK W. HARRINGTON. *Report of the Chief of the Weather Bureau for* 1893. From the Report of the Secretary of Agriculture for 1893. 8vo. Washington, 1894. Pp. 89–122. Pl. 4.

Prof. Harrington's third report as chief of the Weather Bureau is at hand, and furnishes interesting reading as to the condition of the National Weather Service. During the year the work of the Bureau has been carried on successfully and the total cost of maintenance has been reduced by about ten per cent. Among the features of especial interest is the fact that in January, 1893, the entire force of local forecast officials and observers was brought within the classified service by a presidential order, so that since that date all appointments to that force have been made through the Civil Service Commission. There can be no question that this change will result in the improvement of the service, and as a further step in this direction it should be welcomed by all persons interested in the success of the Bureau.

At the date of the publication of the present Report the regular classified observing force of the Bureau consisted of 30 local forecast officials and 269 observers. There were 156 regular paid stations in operation, 14 having been discontinued as useless for the purposes of the Bureau, and 3 new ones having been established. During the World's Fair at Chicago, as already noted in this JOURNAL (September, 1893, pp. 236, 237), the Bureau maintained an exhibit setting forth all the characteristic features of the work; and the complete process of receiving weather reports, preparing maps and forecasts, was daily fully shown and illustrated. Among the recommendations made by Prof. Harrington are the following: a closer co-operation with the weather services of Mexico and the Bahamas, with a view to securing information as to coming weather conditions; uniformity in publication and distribution of the State Weather Service reports; arrangements looking toward the distribution of railway forecasts by the postal clerks on mail trains, and a change in the locations of the three inspectors.

Daily weather maps are issued at seventy-two stations of the Weather Bureau outside of Washington City, the issue amounting to over 2,500,000 annually. In connection with the dissemination of the maps, Prof. Harrington says, "The ideal system of distributing the information collected by the Bureau is one which would place the daily weather map in the hands of the reading public at an early hour, through the daily press or other

medium." We have recently (July, 1894) published an article in this JOURNAL on *The Newspaper Weather Maps of the United States*, in which we stated our belief in the possibility and practicability of having daily weather maps extensively printed in our newspapers, and we believe, with Prof. Harrington, "that present efforts should be directed towards the re production of a legible map in the daily papers, which shall contain the forecasts and such other climatological data as may be of importance to the community in which the paper is printed." If there is a demand on the part of even a small number of readers that a paper shall print daily weather maps, there is little doubt that such maps will, in most cases, be printed. The percentages of verification of the 8 P. M. 24-hour forecasts, east of the Rocky Mountains, were as follows: Weather, 84.4; Temperature, 82; Weather and Temperature combined, 83.4. (For the Pacific Coast Division the percentages were: Weather, 90.3; Temperature, 73.8; Weather and Temperature combined, 83.7). Of the 24-hour *fair weather* forecasts, 90.4 per cent were verified; of the *rain* or *snow* forecasts, 74.1 per cent. Of the *warmer* or *colder* temperature forecasts 82 per cent were verified, and of the *stationary* temperature forecasts 82 per cent. The percentages for the preceding year were respectively 88.8, 70.5, 82.8, 79.2. It will be seen from these figures that there has been a marked improvement in every case but one, and in that there has been a falling off of only .8 per cent. 68.9 per cent of the cold wave signals were justified . An unusually large number of storm warnings was sent out during the year, with marked success, as was especially the case with the cyclones of August 25–27 and October 12–14. Arrangements have been made with the Light-House Board and the superintendent of the Life-Saving Service to secure the announcement by telegraph, from keepers of light-houses and life-saving stations along the Atlantic Coast, of the occurrence of heavy ocean swells, or other signs of the approach of hurricanes. As is well known, the heavy swell caused by a cyclone at sea is often the first indication of the coming storm, and an early announcement of this fact may often result in timely warnings being sent out. The great hurricane of August, 1893, was thus heralded, the report of heavy swell off Tybee Island having been one the earliest intimations of its approach.

The State Weather Services are in a very flourishing condition. Some changes have been made in the location of the central offices of the Alabama, Nebraska, Mississippi, and Washington Weather Services. The number of crop correspondents in 1893 exceeded 9,000. The weekly crop reports, as well as the monthly bulletins, are more and more appreciated by the public. The total number of voluntary observers is about 2,590. The number of stations receiving the forecasts by telegraph or telephone at Government expense on Dec. 31, 1893, was 1,613, while over 7,000 received the information gratuitously. Many railroad companies co-operate with the Bureau in telegraphing the forecasts over their lines, or in distributing the weather bulletins through the medium of the train baggage masters. Weather symbols are displayed on the baggage cars of several railroads, and whistle signals are used to a considerable extent in some States.

In concluding this summary of Prof. Harrington's report, we are glad to quote the following: "Experience has demonstrated that military management and discipline are not essential to an efficient weather service, and it is gratifying to report that the present civilian management has found no difficulty in maintaining the necessary stations at the most isolated points. The employees of the Weather Bureau, with very few exceptions, have performed their duties with absolute promptness and fidelity, and to the faithful and intelligent execution of the arduous labors of the observing force must, in the largest measure, be ascribed the high standard of efficiency which has been attained by the national weather service."

THEOPHRASTUS ON WINDS AND ON WEATHER SIGNS.

THEOPHRASTUS OF ERESUS *On Winds and on Weather Signs.* Translated, with an Introduction and Notes, and an Appendix *On the Direction, Number, and Nomenclature of the Winds in Classical and Later Times,* by Jas. G. Wood, M. A., LL.B., F. G. S., and edited by G. J. Symons, F. R. S. 8vo. London, 1894. Pp. 97, pl. 2, Figs. 2, maps, 2.

To Dr. Hellmann, of Berlin, and to Mr. G. J. Symons, of London, meteorologists are indebted for much valuable information in connection with old and rare works in their science, and also for the publication of reprints of some of these books. Dr. Hellmann has recently begun the publication of his *Neudrucke von Schriften und Karten ueber Meteorologie una Erdmagnetismus,* and three volumes have already been issued, viz., Reynmann's "*Wetterbuechlein,*" Blaise Pascal's "*Récit de la Grande Expérience de l'Equilibre des Liqueurs,*" and Luke Howard's "On the Modifications of Clouds." Mr. Symons has given us "The Cobham Journals," "Cowe's Meteorological Journal," and "Merle's MS. 1337–1344." The present volume is the first of a series of proposed translations which Mr. Symons has had in mind for many years, his plan being to have translated and published the most important ancient works on meteorology. In July, 1892, Mr. Symons asked, through his "Meteorological Magazine," whether anyone would volunteer to prepare a translation of Theophrastus' writings on "Winds and on Weather Signs," and Mr. Wood having been the first to offer his services, he undertook the task, Mr. Symons seeing to the publication, the cost of which has been partly met by subscription.

Mr. Wood's work has been carefully and thoroughly done, and his introduction, notes, and appendix add much to the value of the book. Theophrastus, as we learn from the introduction, was born at Eresus, in Lesbos in or before B. C. 374, and died B. C. 287. He was first a pupil of Plato, at Athens, and after the death of Plato he became attached to Aristotle, with whom he became very intimate. Indeed, Aristotle left to Theophrastus his literary property and his library. After the death of Aristotle, Theophrastus succeeded to the direction of the Lyceum, which the former had founded at Athens, and became the centre of a numerous body of pupils. Among

the less formal writings of Theophrastus are the two papers "On Winds" and "On Weather Signs," which are translated in the volume we are discussing.

The paper "On Winds" deals with the characteristics and effects of the different winds, and the explanation of various weather changes occurring in connection with them. Although interesting to a modern reader, as being one of the earliest writings in meteorology, there is little in the paper to attract attention. The Aristotelian theory of the winds seems very strange to us to-day, and is very difficult to present in words. Aristotle's idea was that air is derived from vapor and smoke, vapor being moist and cold, smoke hot and dry, and air, moist and hot. To produce wind, matter has to be formed, and the more matter the greater the wind. This matter is derived from the earth, and is distinct from vapor. The motion of wind is due to the over-production of the matter, and the effort to restore equilibrium consequent upon this over-production. A good many of Theophrastus's remarks on the winds show him to have been a close and careful observer, and furnish interesting reading. For instance, speaking of the decrease in velocity of the winds at sunset, he says: "Sometimes also at sunset the sun makes the winds to cease, by withdrawing the repulsive motion which it gave earlier [in the day]. And it is clear that this motion has a due proportion [to the force of the sun], so that on the one hand it does not become spent too soon, and on the other hand the wind is not kept longer in motion by it [than while the sun is above the horizon]." Again, speaking of the difference in temperature between land and water in winter and summer, the author says: "In winter and summer, when the wind is cold, it destroys, but when warm it nurtures; and so, in each case, it exerts a preserving power by having a condition of air opposed to that of the season. This happens when the wind is from the sea. For the sea is warm in winter and cold in summer."

The second paper is entitled "On the Signs of Rain, Winds, Storms and Fair Weather," and, as this title implies, deals with weather signs and proverbs. These proverbs relate to the actions of animals, condition of sky at sunset and sunrise, clouds on mountain summits, changes of winds, etc., and some of them are found in our own stock of weather proverbs to-day.

In the Appendix, Mr. Wood has given some valuable notes on the "Nomenclature of Winds in Classical and Later Times." The volume is well gotten up, and is illustrated with two half-tones, of the Horologium of Andronikos at Athens and the Table of the Winds in the Museo Pio Clementino at Rome, two maps showing places mentioned in the text, and two figures giving the names and directions of the winds. Mr. Symons deserves the thanks of meteorologists for his services in bringing out this book.

TITLES OF RECENT PUBLICATIONS

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(An asterisk [*] indicates that the publications thus designated have been received by the Editor of this JOURNAL.)

BADEN. CENTRALBUREAU FÜR METEOROLOGIE UND HYDROGRAPHIE. DEUTSCHES METEOROLOGISCHES JAHRBUCH FÜR 1883. *Die Ergebnisse der meteorologischen Beobachtungen im Jahre* 1893. (Zugleich II. Theil des Jahresberichtes für das Jahr 1893.) 4to. Karlsruhe, 1894. 65 pp. 7 pl.

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*BAVARIA. KÖN. METEOROL. CENTRAL-STATION. DEUTSCHES METEOROLOGISCHES JAHRBUCH FÜR 1893. *Beobachtungen der meteorologischen Stationen im Koenigreich Bayern.* Jahrgang XV., pp. 91–156. 4to. Muenchen, 1894.

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Contains the following meteorological articles: —

Capt. W. deW. Abney. *Transmission of sunlight through the earth's atmosphere.* pp. 1–42.

Lieut.-Gen. R. Strachey. *Harmonic analysis of hourly observations of air temperature and pressure at British Observatories. Part I. Temperature.* pp. 617–646, pl. 19–43.

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